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A 24-YEAR STUDY OF BALD EAGLES ON BESNARD LAKE, SASKATCHEWAN

JON M. GERRARD
Manitoba Institute of Cell Biology, 100 Olivia Street, Winnipeg, Canada R3M 0Y2

PAULINE N. GERRARD AND P. NAOMI GERRARD
Box 113, R.R.1, Headingly, Canada R0H 0J0

GARY R. BORTOLOTTI AND ELSTON H. DZUS
Department of Biology, University of Saskatchewan, Saskatoon, Canada S7N 0W0

ABSTRACT.—Productivity of Bald Eagles (*Haliaeetus leucocephalus*) on Besnard Lake over a 24-year period was relatively stable. Occasional decreases in productivity appear related to weather conditions encountered during spring migration and upon arrival at Besnard Lake. Studies of four marked birds suggest considerable nest site fidelity. Observations of marked eagles in combination with surveys of Bald Eagles on Besnard and other local lakes provide insight into age structure for the local population and into adult mortality rates. We estimate adult mortality in this stable population to be 6.5–7.7%. Population stability appears to be maintained as a result of the eagles' deferring first breeding to age six.

Veinticuatro años de estudios sobre el Águila Cabeciblanca en el Lago Besnard, Saskatchewan

EXTRACTO.—La reproducción del Águila Cabeciblanca (*Haliaeetus leucocephalus*) en el Lago Besnard, en un período de 24 años, ha sido relativamente estable. Un decrecimiento ocasional en la reproducción parece estar relacionado con las condiciones climatológicas que encuentran estas aves en sus migraciones de primavera y a su llegada al área del Lago Besnard. Estudios hechos con cuatro aves marcadas sugieren una considerable fidelidad al sitio de ubicación del nido. Observaciones sobre águilas marcadas, en combinación con conteos poblacionales de esta especie en el Lago Besnard y otros lagos locales, dan una percepción clara tanto de la distribución por edades de la población local como de la proporción en la mortalidad de adultos. En esta población estable, estimamos que la mortalidad en los adultos es de 6.5% a 7.7%. La estabilidad poblacional parece mantenerse por el hecho de que estas águilas difieren, hasta la edad de seis años, el primer ciclo reproductivo.

[Traducción de Eudoxio Paredes-Ruiz]

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*It seems fitting to honor the Hamerstroms by reporting results of a long-term study of a raptor population. Both Frederick and Frances Hamerstrom were keenly interested in raptors and other birds and, as a team, they combined long-term studies first of Greater Prairie Chickens (*Tympanuchus cupido*) and, later, of Northern Harriers (*Circus cyaneus*; Hamerstrom 1986).*

Our focus has been a population of Bald Eagles (*Haliaeetus leucocephalus*) on Besnard Lake in northern Saskatchewan. Studies reported here occurred coincident with considerable concern about the effects of DDT on eagle populations in North America. In this respect, our studies parallel those of Frances Hamerstrom's on the Northern Harrier. However, the harriers studied by Hamerstrom were severely affected by DDT; the Bald Eagles in northern Saskatchewan were sufficiently isolated to escape appreciable detrimental effects due to the pesticide (Whitfield et al. 1974). Furthermore, fish, the primary food of Bald Eagles at Besnard Lake, form a stable prey base and our studies have revealed a relatively stable Bald Eagle population. In contrast, the voles eaten by harriers fluctuate dramatically in numbers (Hamerstrom 1986) as a result of DDT or the shifting availability of food. Our studies have provided evidence for nest and mate fidelity and provide insight into the regulation and limitation of Bald Eagle numbers in a stable population.

STUDY AREA

Besnard Lake, situated along the southern boundary of the Canadian Shield in northern Saskatchewan, has an irregular outline with rocky shores and numerous (255) islands. Its water area is 160 km^2 and its shoreline is 400

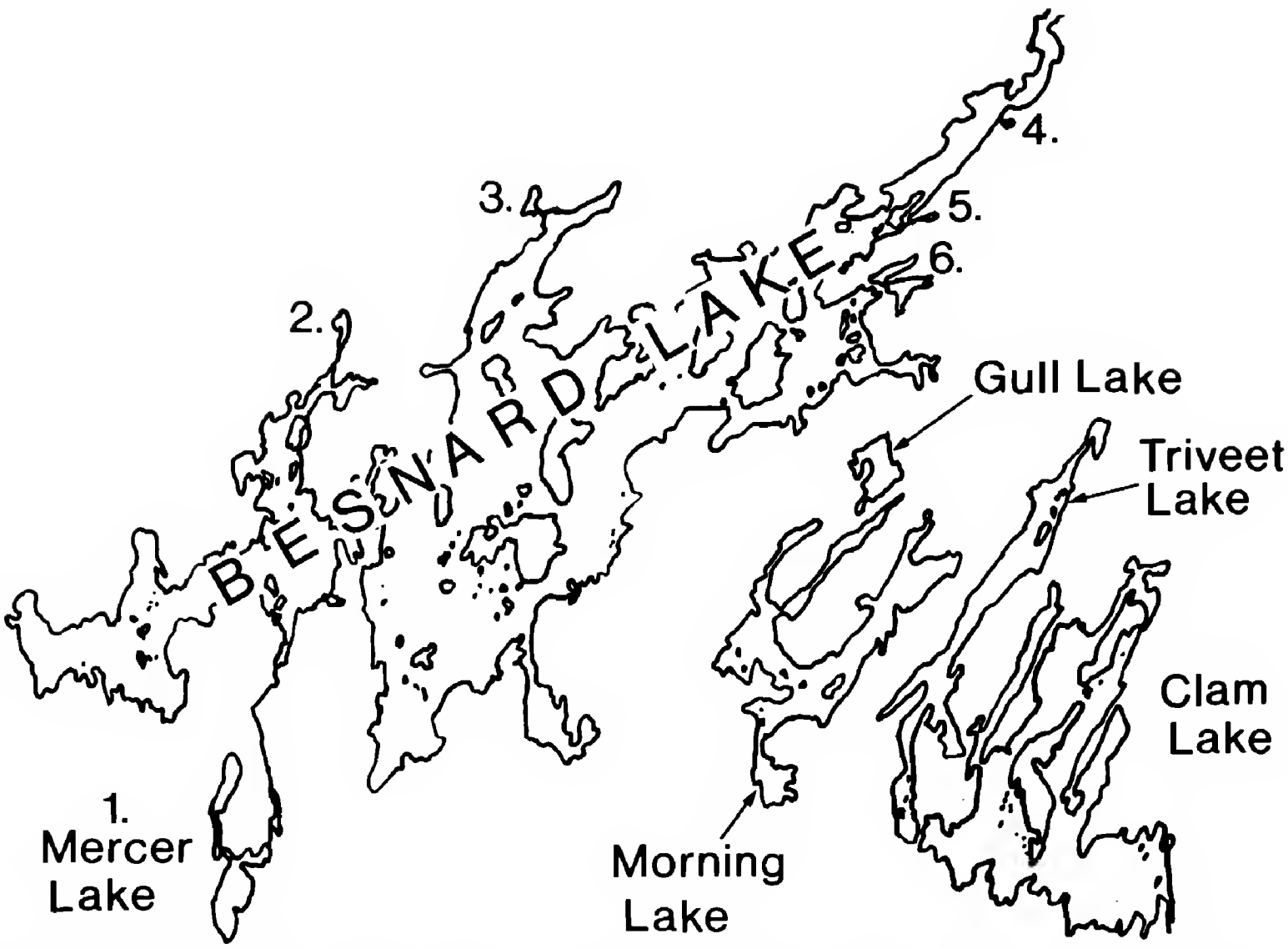

Figure 1. The study area, including Besnard Lake. Those small lakes adjacent to Besnard Lake where streams used for spawning enter Besnard Lake and where immature eagles congregate during May and June are numbered 1–6. Also shown are the lakes of intermediate size: Gull, Morning, Triveet, and Clam lakes.

km in length. It is surrounded by low forested hills not exceeding 100 m in height. White Spruce (*Picea glauca*) and Trembling Aspen (*Populus tremuloides*) predominate near the lake shore. The lake is divided into eastern (75% of the lake area) and western (25% of the lake area) regions, connected only by an 8 meter-wide narrows. The mean depth of Besnard Lake is 7.9 m, giving the lake a water volume of 1.4×10^9 m^3. The maximum depth is 26.8 m. Additional details of the geography, morphology, and biological features are given in Chen et al. (1974).

Besnard Lake freezes over to a depth of up to 2.2 m in the winter. Ice break-up is usually in mid-May. Bald Eagles return at the end of March or in early April and remain as late as freeze-up, which is usually in mid- to late November. Migratory patterns of Besnard Lake Bald Eagles have been described elsewhere (Gerrard et al. 1978). The study area also includes six small lakes at 0.4–3.7 km^2 water area near Besnard Lake (Numbers 1–6, Fig. 1). The character of the shores and forests surrounding these lakes is similar to Besnard Lake, except that one small lake (Mercer Lake) has extensive shallow, reedy areas.

Four intermediate sized lakes (Gull, Morning, Triveet, and Clam), as shown in Figure 1, were included for certain studies. These lakes are near to Besnard Lake and similar to Besnard and are located along the southern boundary of the Canadian Shield region (Gerrard and Gerrard 1985, Dzus and Gerrard 1989). As with Besnard Lake, these lakes have irregular outlines with rocky shores and numerous islands. The total shoreline of all four lakes is 360 km^2, slightly less than the total shoreline of Besnard Lake. The terrain is similar to Besnard Lake, although Morning Lake is distinctive in having several large bays with substantial amounts of wild rice.

METHODS

Bald Eagle productivity on Besnard Lake has been checked annually since 1968. Status of nests was usually evaluated as recommended by Postupalsky (1974) during incubation in April or May, and then at intervals during June, July and August. Aerial censuses were performed in July 1968, May 1969, July 1969, April 1970, April 1973, May 1974, April 1986 and May 1987. All other censuses were conducted by boat, as previously described (Gerrard et al. 1990) with one or more observers travelling 100 m from the shore in a motorboat at a speed of 8–16 km/hr covering alternate 8 km sections of lake shoreline with half the lake (25 sections) covered in a survey. Ob-

Table 1. Breeding areas and reproductive indices for Bald Eagles at Besnard Lake, Saskatchewan (1968–91).

YEAR	BREEDING AREAS	PERCENTAGE OF SUCCESSFUL BREEDING AREAS[b]	NUMBER OF YOUNG PER OCCUPIED BREEDING AREA	NUMBER OF YOUNG PER SUCCESSFUL BREEDING AREA	NUMBER OF YOUNG FLEDGED
1968[a]	8	83	1.33–1.5	1.6–1.8	8–9
1969[a]	16	67	1.0–1.2	1.5–1.8	15–18
1970[a]	16	75	1.25	1.67	20
1971[a]	15	53–80	1.0–1.5	1.88	15
1972[a]	16	75–80	1.06–1.13	1.42	17
1973	25	68	0.88–0.96	1.3–1.44	22–24
1974	25	65	0.96	1.47	22
1975	25	46–61	0.63–0.83	1.36	15
1976	25	67	1.14	1.71	24
1977	24	78–82	1.26–1.32	1.61	29
1978	25	74	1.17–1.22	1.59–1.64	27–28
1979	24	79	1.26	1.60	24
1980	24	74–77	1.22–1.27	1.65	28
1981	24	67	1.19	1.79	25
1982	24	81	1.38	1.71	29
1983	24	83	1.56	1.67	25
1984	25–26	72–75	1.35	1.72	31
1985	28	58	0.95	1.64	23
1986	31–36	50–58	0.75–0.87	1.50	21
1987	29	70	1.11	1.58	30
1988	29	66	1.22	1.74	33
1989	25-26	77–80	1.23–1.28	1.60	32
1990	29	56	0.81	1.47	22
1991	28	52–54	0.92–0.96	1.77	23

[a] Coverage was possibly incomplete.

[b] Successful breeding areas/occupied breeding areas.

servers were on the lake for 1–5 mo in all years except 1971, when a single boat census was conducted in July, and in 1983, 1985, 1989, 1990 and 1991 when the observation period was restricted to 2–3 wk in July.

We have used the following terms (Gerrard et al. 1983). A breeding area refers to one or more Bald Eagle nests within the range of a mated pair. An occupied breeding area is one with a mated pair consistently using the area that year. An active breeding area represents one in which at least one egg was laid. A successful breeding area is one where one or more young were raised to fledging.

Red, yellow, and green patagial tags were used to mark 56 nestling eagles on Besnard Lake from 1973–75 (Gerrard et al. 1978). Two nesting adults were captured as described by Harmata (1985) and marked using colored and numbered leg bands, one in 1988 and one in 1989. Age and sex of nestling Bald Eagles were determined using criteria described by Bortolotti (1984).

RESULTS

Table 1 provides the number of breeding areas and several reproductive indices for Bald Eagles on Besnard Lake, 1968–91. Number of young raised per occupied breeding area has varied through the years 1968–91. The years 1973–75, 1985–86, 1990–91 showed values of less than one young produced per occupied breeding area. There was a particularly sharp decrease in productivity in 1975.

Population Stability. Fifty-three ± 1.1 ($\bar{x} \pm$ SE) Bald Eagles were seen on six surveys in July 1976–79, giving an estimated lake population (nestlings excluded) of 106 eagles. Forty-nine and 54 Bald Eagles were seen on six surveys in July 1990, for an estimated lake population of 103 eagles.

Nest Site and Mate Fidelity. A female hatched on Besnard Lake in 1973 occupied nest Y with a mate in 1979 at age 6, and bred successfully from 1980–91, with the exception of 1990 (Table 2). A female hatched on Besnard Lake in 1974 was first observed at nest M in 1984 and has bred successfully

Table 2. Sightings of nesting adults marked as nestlings or adults on the Besnard Lake study area and their subsequent nesting success, 1979–91.

	YOUNG FLEDGED BY MARKED EAGLES			
YEAR	Y (FEMALE)	M (FEMALE)	O (MALE)	T (FEMALE)
1979	0			
1980	2			
1981	2			
1982	2			
1983	2			
1984	2	2		
1985	1	not seen		
1986	2	1		
1987	2	2	2	
1988	3	2	2	2
1989	2	2	2	2
1990	0	0	not seen	0
1991	3	2	not seen	0

on this territory for six of eight years from 1984–91. A male hatched on Besnard Lake in 1980 bred for three successive years during 1987–89 at nest Θ. A female captured as an adult at nest T in 1988 bred in 1988 and 1989 and has continued in the same territory with a mate in 1990 and 1991. Additional data suggest that unmarked females repeatedly used the same breeding area. There was a significant correlation ($r = 0.907$, $df = 4$, $P < 0.05$) between the lengths of eggs collected at the same nest in two different years (order in the laying sequence within the clutch was held constant between years). Variation in egg length among nests was three times greater than variation within nests compared among years. Behavior of pairs (e.g., tame or aggressive in response to investigators climbing their nest trees) was consistent throughout 1980–82; there was a very high correlation between the aggressiveness in nest defense score between two consecutive years ($r = 0.955$, $df = 6$, $P < 0.01$). Each breeding area was represented only once in the latter analysis to maintain the independence of samples. Breeding areas with young in all three years were consistent in the aggressiveness of attending pairs (e.g., the mean scores for the three years for three nests were 1.9, 1.8, 2.0, and 4.4, 4.9, 4.8, and 3.6, 3.6, 3.8). We noticed consistencies in the behavior of many pairs for several years before we quantified nest defence.

Overall Population Composition. Using data from boat censuses of Besnard Lake (Gerrard et al. 1990) and adjacent small and intermediate-sized lakes (Dzus and Gerrard 1989) we estimated the proportion of Bald Eagles in different age categories for this area for May and June and for July and August (Table 3). Of all eagles (nestlings included), 25–30% were adults at active nests, 4–5% were adults at inactive or failed nests, 13–19% were adults not associated with nests, and 30–33% were immatures. The nestlings raised on Besnard Lake made up 18–22% of the population at the end of the summer. Information on the age and composition of a population can be used to estimate survival rates for immatures and adults (Sherrod et al. 1976). Knowing that the Besnard Lake eagle population has been stable for many years, and using the data in Table 3, we calculated mortality rates for eagles in the Besnard Lake population. Based on studies of color marked eagles (three color marked adults seen at age four were not breeding; three color marked birds seen at age five were not breeding; one color marked bird occupied a breeding territory at age six and successfully raised young for the first time at age seven), we estimate that adult eagles at Besnard Lake enter the breeding population at the average age of six. In a stable population, adult mortality must equal recruitment into the breeding populations. Given a population (Table 3) with nestlings comprising 20–21% of the population, 1–3 year olds comprising 31–32%, 4 and 5 year olds comprising 17–19%, and eagles 6 or more years old comprising 30–33%, the maximum yearly adult mortality can be no greater than 7.7% (Table 4). If Bald Eagle mortality declined over the first few years (Table 5), then adult mortality could be as low as 6.5%. It should be noted that even if Bald Eagles bred at age 4, adult mortality would only increase to 8.8% (Table 6).

DISCUSSION

Results of the study on Besnard Lake give insight into population dynamics of a stable Bald Eagle population. Before 1973, some nests may have been overlooked. However, aerial censuses were conducted in Spring 1969 and in April 1970. Furthermore, observers were on the lake for 6 wk in 1970 and for the full summer of 1972. Thus, while we are cautious in saying that there may have been nests missed in the early years, these were probably few, and some increase in the number of breeding eagles

Table 3. The number and percentage of Bald Eagles for A) all May and June censuses and the mean number of each category of eagles seen on Besnard Lake, the intermediate lakes and the small lakes; B) the July and August censuses for Besnard Lake, the intermediate lakes and the small lakes, and C) all July and August censuses of Besnard Lake only.

				Percent of		
			Number of Eagles	Adults	Eagles (Nestlings Excluded)	All Eagles (Nestlings Included)
I.	Adults at nests where eggs were laid	A) May/June (study area)	60.5	51.7	30.6	25.0
		B) July/August (study area)	61.5	62.8	38.3	29.9
		C) July/August (Besnard Lake)	37.5	61.9	37.8	29.6
II.	Adults at nests where no eggs were laid	A) May/June (study area)	9.7	8.3	4.9	4.0
		B) July/August (study area)	8.5	8.7	5.3	4.1
		C) July/August (Besnard Lake)	6.5	10.7	6.5	5.1
III.	Adults not associated with nests	A) May/June (study area)	46.75	40.0	23.6	19.3
		B) July/August (study area)	28.0	28.6	17.5	13.6
		C) July/August (Besnard Lake)	16.6	27.4	16.7	13.3
IV.	Immatures (Aged 1–3 yr)	A) May/June (study area)	81.0	—	40.9	33.4
		B) July/August (study area)	62.4	—	38.9	30.4
		C) July/August (Besnard Lake)	38.7	—	39.0	30.5
V.	Nestlings	A) May/June (study area)	44.4	—	—	18.3
		B) July/August (study area)	45.0	—	—	21.9
		C) July/August (Besnard Lake)	27.5	—	—	21.7

likely occurred from 1969–73. Further, the number of occupied breeding areas from 1984–91 was, in general, slightly higher than the number from 1973–83. Thus, there has been a modest increase in the number of breeding adults on Besnard Lake during the years of the study. Boat censuses designed to evaluate the overall population (Gerrard et al. 1990) suggest that the total number of Bald Eagles using Besnard Lake has not changed from 1976–90.

Primary prey utilized by this population was fish, a prey base which for Besnard Lake has been relatively stable. There has been increased fishing pressure and a noticeable decrease in the size of walleye (*Stizostedion vitreum*) caught by fishermen (J.M.G.

Table 4. Estimate of Bald Eagle mortality rates at Besnard Lake assuming mortality constant after year one and age at first breeding = 6.

Age Class	Percentage of Population	Mortality
Fledglings	20.10%	43%
1 year old	11.50%	7.7%
2 years old	10.61%	7.7%
3 years old	9.80%	7.7%
4 years old	9.04%	7.7%
5 years old	8.34%	7.7%
6 years old	7.70%	7.7%
7 or more years old	22.91%	7.7%

Table 5. Estimate of Bald Eagle survival with mortality decreasing until age 6 and age at first breeding = 6.

Age Class	Percent of Population	Mortality
Fledglings	20.10%	36%
1 year old	12.86%	20%
2 years old	10.79%	15%
3 years old	8.74%	11%
4 years old	7.78%	9%
5 years old	7.08%	7.5%
6 years old	6.55%	6.5%
7 or more years old	26.60%	6.5%

Table 6. Maximum estimate of adult Bald Eagle mortality rate assuming mortality constant after year one and age at first breeding = 4.

AGE CLASS	PERCENT OF POPULATION	MORTALITY
Fledglings	20.10%	42%
1 year old	11.65%	8.8%
2 years old	10.62%	8.8%
3 years old	9.69%	8.8%
4 years old	8.84%	8.8%
5 or more years old	39.10%	8.8%

personal observations), and a decrease in the number of the largest sizes of northern pike (*Exos lucius*). It is possible that fish such as cisco (*Coregonus artedis*) may have increased with fewer predatory walleye and pike. Bald Eagles preferentially feed on cisco (Gerrard and Bortolotti 1988) and numbers of Bald Eagles on Besnard and Nemeiben lakes have been related to number of cisco in these two lakes (Dzus 1988). A modest increase in cisco from 1973–91 is one potential explanation for a modest increase in breeding eagles.

Association of poor productivity in Bald Eagles with weather conditions in spring is consistent with data from other areas, suggesting that spring conditions may limit breeding success (Leighton et al. 1979, Swenson et al. 1986). In 1975 a series of severe snowstorms swept across northern Saskatchewan during eagle migration, severely disrupting their return to the nesting grounds (Gerrard and Whitfield 1979). We suspect that females arrived back in poor shape and bred much less successfully than usual. The decrease in young raised on Besnard Lake in 1975 was reflected over a fairly wide area of northern Saskatchewan and perhaps adjacent Manitoba, Alberta, and the Northwest Territories. There was a significant decrease in the number of immature eagles seen on the wintering grounds on the Christmas bird counts in 1975–77, consistent with the observed decrease in productivity in 1975 (Gerrard and Whitfield 1979). Although analyzed in much less detail, 1990 appears to have been similar to 1975. At the time that eagles return, the lake is usually still frozen and fish or other prey may be difficult to find. This is a time when food is limited and it is likely that the condition of adults based on their winter feeding pattern (Harmata 1984), their experience during migration, and in the first few days at Besnard Lake has a significant influence on breeding success.

Observations of four color marked eagles show considerable nest site fidelity and imply, therefore, a degree of mate fidelity. In addition to our observations of marked eagles, evidence from egg measurements and from observations of behavior supports the concept that the same pairs inhabited the same breeding areas year after year. A further example of nest fidelity was a female, identifiable by unique plumage, which was an occupant of one breeding area from at least 1979–81 (Bortolotti and Honeyman 1985). Taken together, these observations suggest strong nest site and mate fidelity in this population of Bald Eagles.

Estimating the age structure of the Bald Eagle population is difficult when there has been some movement on and off Besnard. The May/June data for Besnard Lake alone, or for the intermediate-sized lakes alone show that the various age classes were unevenly distributed within the study area, with the immatures and non-breeding adults gathering at spawning streams and small lakes with winter kill of fish during May and June (Gerrard et al. 1990). Combining estimates of numbers of eagles in May and June on Besnard Lake with numbers from adjacent intermediate and small lakes is necessary to give a reasonable estimate of the proportion of breeding adults, non-breeding adults, and immatures in the overall population. There was a redistribution of eagles between June and July. Nevertheless, the proportion of eagles in the regional population in May and June was very similar to the proportions seen in July and August (Table 3), providing support for the reliability of the data. Furthermore, we found the eagle population on Besnard Lake in July and August was representative of the overall population for the region, showing that the various age classes are more evenly distributed within the study area at this time (Gerrard et al. 1990).

The percent of adults not associated with nests on Besnard Lake (27–40%) shows that a significant proportion of the adults do not breed. Observations of marked birds suggest that the majority of these are the younger adults (4 and 5 years of age) and these were more numerous in our study than on Amchitka Island where essentially none were observed (Sherrod et al. 1976), and less numerous than the 86% of adults found not breeding in 1979 in southeast Alaska (Hansen and Hodges 1985). A low rate of non-breeding eagles on Amchitka Island may

have reflected the changing status of that population, which appeared to be increasing during the study period, perhaps as a result of the increased availability of food in winter. Evidence from elsewhere is also consistent with the concept that where food resources are not limiting, Bald Eagles will breed at four years of age (Nye 1983). Hansen and Hodges could not explain the high rate of non-breeders in southeast Alaska, although a decrease in food resources was mentioned as a possibility. Our finding that eagles in northern Saskatchewan may not begin breeding until age six suggests that in this saturated population, eagles may have to delay breeding until they are able to compete successfully for the limited breeding territories and the associated fish resources.

Our estimates for adult mortality suggest that it is likely between 6.5% (seen with maximum decline in mortality over the first six years) and 7.7% (estimated with mortality unchanged after the first year).

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